Research on The Problem of Magnetic saturation controllable reactor Operating Characteristic

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Abstract. In this paper, the main work is focused on the study of the magnetic saturation controllable reactor operating characteristics. Finite element analysis has been used to build the model of 10kV magnetic saturation controllable reactor, then compared with the experimental values calculated control characteristics, volt-ampere characteristic and harmonic characteristics in simulation. The analysis of 10kV controllable reactor working performance has been completed which can give guidance for the research of magnetic saturation controllable reactor operating characteristics.

1. Introduction

Magnetic saturation type reactor as a controllable one is very important and it is an important component used for voltage controlled and reactive power compensation. It can improve system stability and power quality with quite wide range of applications, so its research has not been stopped [1-3]. In the power system, magnetic saturation type reactor is widely used to compensate for the capacitive chargingpower to limit power frequency over-voltage, limit operation over-voltage, suppress the supply current, and eliminate the generator self-excitation. It is also used in controllable series reactor to limit the short-circuit current, starting reactor in electrodeless soft starting system of large motor ,and the distribution network for automatic arc suppression coil. They all need real-time adjustment and control according to operating conditions [4-5]. Magnetic saturation reactor with its superior performance will become an integral part of future electricity grid equipment, and the study of magnetic saturation reactor has being continuing. With the development of power systems, magnetic saturation controllable reactor increasingly plays an important role, while the performance of magnetic saturation controllable reactor has become increasingly demanding [6].

This paper has studied the operating characteristics of the magnetic saturation controllable reactor, compared the experimental values and simulation values within the tolerance error range, and verified the accuracy of the method. For future research, it provides an important basis for the dynamic characteristics of UHV magnetic saturation type controllable reactor.

2. The principle of magnetically controlled saturated reactor

The model of magnetically controlled saturated reactor has been analyzed ,and the working winding and control winding are marked.Working windings are parallelled and magnetic lines of force through this windings are in the same direction,while control windings are reverse connected in series,and one line of force is up, another one is down. The aim is to make the core column in depth of magnetic saturation under the action of control winding DC current.

The effects of control windings are two:

(1).Control winding increases the magnetic field of a core column, and counteracts the other one.

(2).Due to the control winding load DC current, the magnetic induction intensity weakened the core columns alternating current produces magnetic flux can not enter the core columns, while the saturation magnetic induction intensity of the core column depth of the magnetic induction intensity is strengthened, then core permeability decreased rapidly, so as to achieve for the electricity grid to provide a large number of non-reactive power.

Table 1 the winding parameters of controlled reactor

	turns	ohm(Ω)	rated current（A）	rated voltage（kV）
work winding	1660	2.2246	63	$11/\sqrt{3}$
control winding	581	0.25	180	--

We measure the magnetically controlled saturated reactor with the structural parameters and the winding parameters, which are consistent with the physical. Tab. 1 shows the winding parameters.

3. Magnetic field distribution and the characteristic analysis of magnetically saturated controllable reactors

3.1 The flux density distribution of stable runtime

In order to be able to comprehensive analysis magnetic saturation type controlled reactor in the whole working range of the magnetic field distribution, this paper mainly discusses the control current of 45 A, 110 A, 180 A the distribution of magnetic field of magnetic saturation type controlled reactor are analyzed, among 110 A is rated working condition control winding current value. Fig. 1 shows flux density figure of dc source is 45A stable all the time.

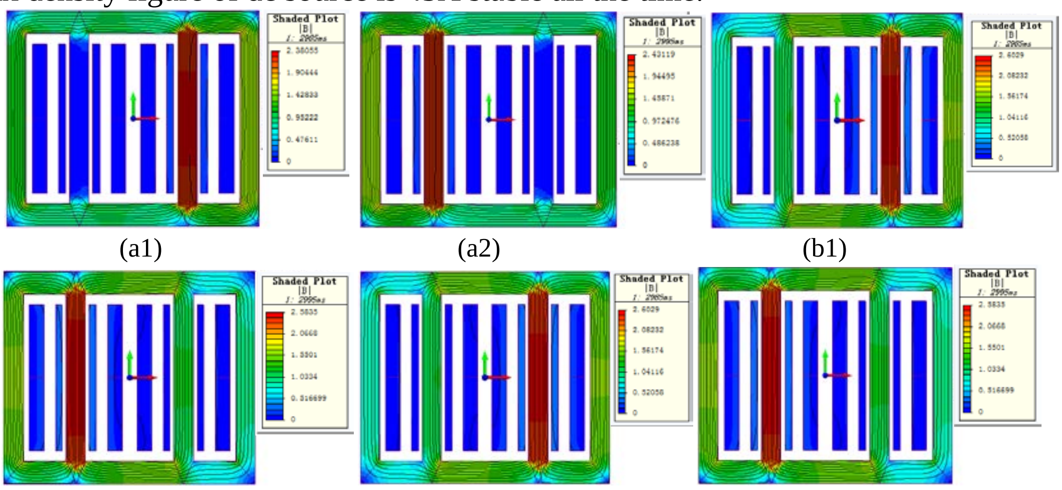


Figure 1 flux density distribution of dc source load 45A (a) 110A (b) and 180 A (c)

Fig. 1shows flux density distribution when the dc source is 110A、180A stability. According to the different control electric magnetic flux density distribution: with the increase of control current, the core of magnetic flux density is also increasing; degree of saturation increases continuously, namely core around the bower column by alternating saturated tend to be fully saturated; with the increase of control current flows through the yoke of the dc magnetic flux increasing.

3.2 Control characteristic

Control characteristic is refers to the working winding current effective value and control winding current of magnetic saturation type controlled reactor. In order to get the control characteristics, it is necessary to calculate winding current valid values of different control power flow. So in this paper, the formula (3.1) is used to calculate virtual value.

$$I = \sqrt{\frac{1}{T}\int_0^T i^2 dt} \tag{3.1}$$

where, T is waveform cycle, I is the virtual value of working winding current.

When the control winding is 6.2 A, 45 A, 85.8 A, 136 A, 180 A, 274 A respectively, simulation work on winding current value were compared with the experimental value. Table 2 shows the simulation value and experiment value contrast, Fig. 2 shows control characteristic figure.

Table 3 the simulation value compared with the experimental value

Control current/A	6.2	45	85.8	136	160	180
Experimental value/A	3.6	20.8	35.4	52.5	60.3	65.6
Simulation value/A	3.6	21.1	36.5	53.1	60.4	66.2
Error%	0	1.4	2.5	1.1	1.6	0.9

Through the simulation value and experiment value in table 3 draw the control characteristic graph. After comparing with the experimental value, can be seen from the table in the experimental value and the simulation value of error is less than 5%, which verified the accuracy of the simulation results for the basis of Uhv magnetic saturation type controlled reactor.

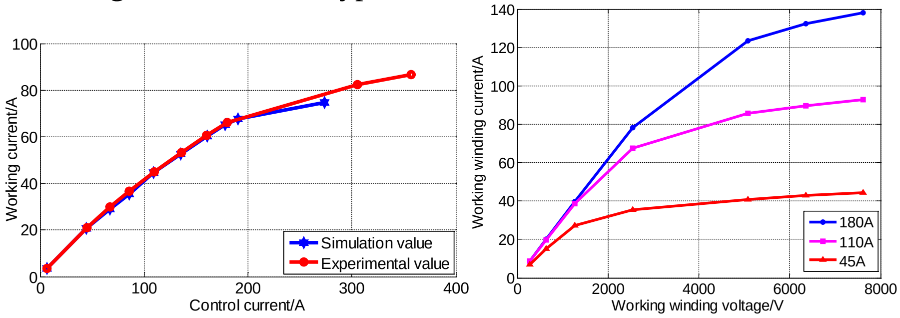


Figure 2 control characteristic figure, current and voltage characteristics under different control current

3.3 Volt-ampere characteristics

In the control side, respectively, with 45A, 110A, 180A current source, in turn, change the network voltage to get the fig 2.From the volt-ampere characteristics:

(1) Under the same working voltage, the greater the working current, the smaller of the equivalent reactance value.

(2) The volt-ampere characteristics of magnetic control type saturable reactor has obvious segmentation, which low working voltage, working current increase more quickly. When the work voltage is higher than a certain value, the working current of the speed increase has slowed.

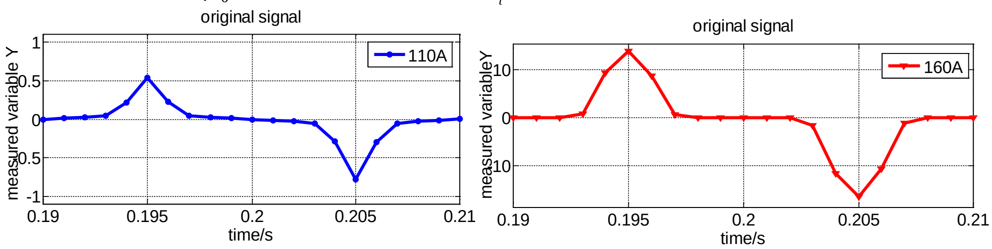
3.4 Harmonic characteristics

Magnetic saturation controlled reactor core contains the dc component of the magnetic flux, so the jobs in the system due to the dc excitation winding current harmonic component, is contained in the generated harmonics into the UHV grid, is bound to cause sine voltage, sinusoidal current waveform distortion; Into the grid as a result, the magnetic saturation type controlled reactor run before, need to work on UHV magnetic saturation type controlled reactor winding current harmonic analysis.

Magnetic saturation controllable reactor reactance can be determined by the following formula:

$$X_L = \omega N^2 A_C \mu\mu_0 / L_t \tag{3.2}$$

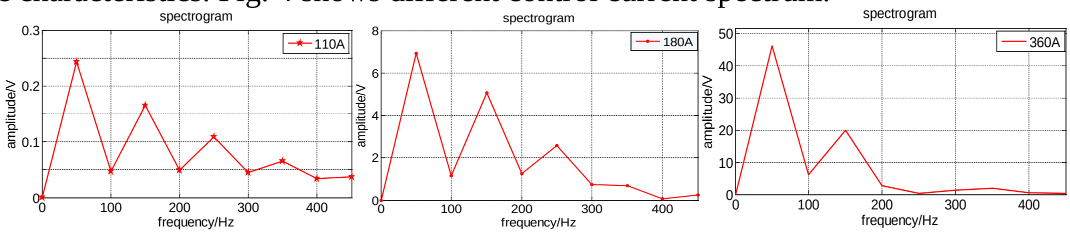
ω is angular frequency, A_C is the cross-sectional area ofcore limb. N is number of turns of winding, μ is core relative permeability, μ_0 is air permeability, L_t is effective length of magnetic circuit.



(a)110A (b)180A

Figure 3 working winding current waveforms under different control currents

Figure 3 shows the stable after the control current of 110 A and 180 A network side winding current waveform of one cycle,winding current waveform is fastigium wave.Harmonic content is bigger,this is the special structure and Magnetic saturation controllable reactor core together with the nonlinear magnetic characteristics. Fig. 4 shows different control current spectrum.



(a)110A (b)180A (c)360A

Figure4 different control current spectrum

From Fig. 4，we can get that with the increase of the current, the spectrum of the harmonic amplitude will become bigger, and the harmonic content is bigger.

According to the experimental analysis, the 3, 5 and 7 harmonic curve of the working current. The working winding load the rated voltage and the control winding load the DC source is given out. Fig. 5 shows relationship between DC and working current harmonics content.

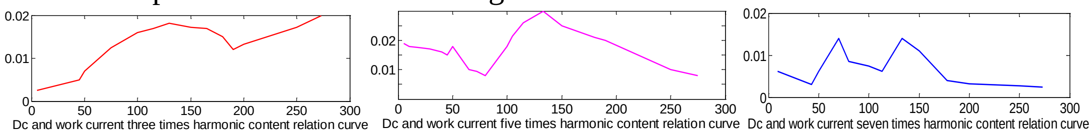


Figure 5 relationship between DC and working current harmonics content

Through the experiment, we can get the 3, 5 and 7 times of the harmonic content, which proves that the odd harmonic content is verified .The 3 time can be eliminated by the compensation winding of three phase angle. 5 times and 7 times by the filter device filter.

4. Conclusion

In this paper, a 10kV magnetic saturation controllable reactor was simulation in MAGNET. It analyzed the control characteristics, the voltage characteristic and harmonious wave characteristics, then done the experimental tests. Comparison of the experimental values and the simulation value, we can get that the magnetic saturation controllable reactor is within the allowable range of error. This can verify the accuracy of the program and get the results that the magnetic flux density core current increased with the control current increasing under the different control current. It provides the basis for the study of UHV magnetic saturation controlled reactor.

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